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TRAFFIC AIRSHIPS WITH SPECIAL REFERENCE TO ECONOMY.

By

Walther Leyensetter.

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Taken from
"Zeitschrift für Flugtechnik und Motorluftschiffahrt,"
October 30, and November 15, 1920.

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Introduction.

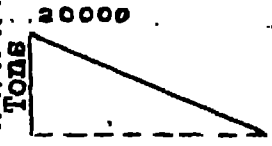





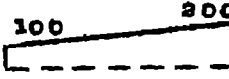

As a result of the progress in the construction of airships during the War, the question naturally arises as to their adaptability to economical transportation.

The airship is expected to enter into competition with the existing means of transportation and to carry on air traffic along with the airplane.

In a general way, the following table** shows the available fields for aircraft:

* Taken from "Zeitschrift für Flugtechnik und Motorluftschiffahrt," October 30, and November 15, 1920.

** See table, Page 2.

Convey- ing Medium :	Water	Land	Air	Electricity.
Realm of trans- porta- ble weight.				
Speed realm				
	Boats propel- led by muscle, wind or engine power.	Passenger cars or trains with or without rails.	Without gener- al economic significance. Only for dif- ficulty acces- sible points without other transportation lines for ur- gent delivery of samples, etc.	
Passen- gers	Ditto	Ditto	Air- planes for communica- tion between places where especi- ally quick travel is nec- essary or where the ship cost of build- ing other lines is too high;	Air- ships for communica- tion between places where the in- crease in speed over land or ship travel is great enough Telegraph Telephone
News	Mail	Mail	Air mail, as above for freight and passengers.	Telegraph Telephone

It follows that air transportation constitutes an organic extension of land transportation, but without the load exceeding 20000 kg. and without materially reducing the great jump in speed from 150 km/h (electric express) to 1,020,000,000 km/h (telegraph).

It can therefore seldom be a question of ordinary freight, but chiefly of passengers, urgent letters, samples of goods, etc.

An aircraft line is consequently always able to compete, when it utilizes its advantage (shared in common with boats) of saving the expense of construction and upkeep of railroads.

Their ability to compete is unimpaired when their superiority depends only on the shorter duration of the trip, in connection with which the element of danger and dependence on the weather works to their disadvantage.

I. TECHNICAL VIEWPOINTS.

1. Flight Altitude and Efficiency.

The propeller thrust P , for a given engine power N_1 , is

$$P = \psi \cdot \pi \cdot r^4 \cdot \omega^2 \cdot \frac{\gamma}{8} \dots \dots \dots (1)$$

$$N_1 = \mu \cdot \frac{\pi}{75} \cdot r^5 \cdot \omega^3 \cdot \frac{\gamma}{8} \dots \dots \dots (2)$$

in which μ and ψ represent numbers dependent on $\frac{v}{r \cdot \omega}$

r , the propeller radius in m,

ω , angular speed in 1/s,

γ , air density in kg/m³.

g , acceleration due to gravity in m/s².

This thrust equals the total resistance of the aircraft.

$$W = (\sum \zeta_w : F + \sum \xi_w J^{2/3}) \frac{\gamma}{g} v^2 \dots \dots (3)$$

in which

ζ_w , represents the drag coefficient for surfaces,

F , the frontal surface in sq.m.,

ξ_w , drag coefficient for objects,

$J^{2/3}$, total surface in sq.m.

v , speed of aircraft in m/s.

If the engine power N_1 and the aircraft speed v remain constant, it follows since all other quantities* are invariable and γ/g only appear linearly in equations 1, 2, and 3, that under these conditions the flight altitude of the aircraft makes no difference (with ordinary engines).

For engines with ordinary carburetors, the power diminishes more rapidly than the air density as was found by experiments in the vacuum chamber.** For these engines there was a connection between horsepower and air density, according to the equation:

* This does not hold quite true for ζ_w and ξ_w . Since, however, tests have not yet been made of the changeability of these two values for changing γ/g and it may be assumed that ψ and μ change in quite similar manner, they may be here regarded as constant.

** See "Zeitschrift des Vereines Deutscher Ingenieure," 1919, Vol. 63, W. G. Noack, Airplane Superchargers, p. 995 (For translation see N.A.C.A. 3161-32), and T.B., Vol. III, No. 1, pp. 1-10 (For translation see N.A.C.A. 3001 Daimler/3).

$$N_e = \sqrt{n^2 \gamma - m + o} \dots \dots \dots (4)$$

in which n , m , and o are known.

Overdimensioned and high compression engines lies at an altitude of 2500 m. The variations in consumption are so small up to 3000 m. that, from the standpoint of efficiency and fuel economy, high compression engines are the best for airships.*

The endeavor to maintain the greatest possible economy of fuel, independently of the air density, is manifested by its reaction on the propeller.

To obtain the highest propeller efficiency is less important in itself than to adapt the propeller output to the working conditions of the engine.

The influence of the variations in torque and r.p.m. on the efficiency of propellers is shown by Fig. 1, which is taken from the publications of Schaffran ("Zeitschrift für Flugtechnik und Motorluftschiffahrt," 1917, pp. 49, 93 and 109) on systematic propeller experiments.

From this figure it is manifest that if the revolution speed n , and the diameter D are constant, then the efficiency η_p is greatest for a given torque M .

The field within which η_p changes by like amounts, constantly increases with the effective climbing ratio H_w/D .

When, therefore, the revolution speed n and the diameter D remain constant, it is advantageous to take the effective pitch and therewith the speed v_r as great as possible, since with a

large H_w/D the absolute value of the propeller efficiency η_p
 *See "Zeitschrift für Flugtechnik und Motorluftschiffahrt," 1920, No. 10, p. 137, "Der Flugmotor in Verschiedenen Luftdichten," by O. Schwager, and "Zeitschrift für Flugtechnik und Motorluftschiffahrt," 1920, No. 13, p. 185, "Hohenleistung von Verbrennungsmotoren," by Wiloke.

increases, as also with decreasing engine power, L ($M = 71620 \frac{N}{n}$) decreases less than with a small H_w/D (narrow-bladed propellers).

For small variations in the r.p.m. and in torque, the decrease in propeller efficiency is of subordinate importance.

The increase in the r.p.m. of the propeller, due to increasing air density with constant engine power, demands however special measures.

The variation of the propeller speed through

(a) a variable gear-shift, has the disadvantage of increased weight, considerably more noise and objectionable acceleration of the propeller in thin air.

(b) regulation of the engine speed, has the disadvantage of increasing fuel consumption by departing from the most favorable r.p.m., and of vibrations of the whole engine group on approaching the critical r.p.m.

The most promising method is by changing the pitch of the propeller* in order, with changing air density, to retain approximately the same efficiency.

Tested specimens of adjustable blades designed by Helix, Hirth, Lorenzen and others have demonstrated their practicability and the possibility of making them of other materials than wood.

While an airplane in climbing requires an increase ΔL in the engine output per second.

$$\Delta L = G \sin \varphi \cdot v_g \dots \dots \dots (5)$$

* Article by Prof. C. Eberhardt in "Motorwagen," 1919, p.309, on adjustable propellers.

in which G = weight of airplane,

φ = climbing angle,

v_s = climbing speed,

an airship has a constant lift up to a certain altitude. The choice of this altitude has a bearing on the percentage composition of the gas at the starting point.

In accordance with the barometric altitude formula, without reference to temperature changes, we have:

$$H' - H = 18,400 \log \left(\frac{1}{1 - \frac{V'}{V}} \right) = - 2,000 \log \text{ nat} \left(1 - \frac{V'}{V} \right)$$

in which $H' - H$ is the difference in altitude up to which no blowing off shall occur,

V , the gas volume at beginning of ascent,

V' , increase of gas volume at altitude H' ,

hence $V + V'$, total gas volume of airship.

From the above equation follows

$$\frac{V'}{V} = \frac{H' - H}{8000} - \frac{(H' - H)^2}{8000^2 \cdot 2} + \frac{(H' - H)^3}{8000^3 \cdot 6} - \frac{(H' - H)^4}{8000^4 \cdot 24} \dots \dots \dots (6)$$

$H' - H = 500, 1000, 1500, 2000, 2500, 3000, 4000, 5000 \text{ m.}$

$$\frac{V'}{V} = 6.06 \quad 12.77 \quad 17.1 \quad 23.1 \quad 26.8 \quad 31.3 \quad 39.3 \quad 46.4\%$$

Fig. 2 shows the utilizable gas volume in terms of the flight altitude. A partially inflated airship always has the same supporting power both in ascending and in descending. A full airship loses about 1% of its total lifting power for every 100 feet of

ascent. Mechanical ascent of a full airship is always uneconomical, resulting in a loss of both fuel and efficiency.

With reference to engine power and propeller efficiency, as well as for avoiding needless loss of gas, we are restricted to a maximum difference of about 2500 m. between the starting and flight altitude.

2. Flight Speed.

The necessity for war aircraft to reduce the air resistance, has exhausted the possibilities so far that the limits in the practical production of streamlined coverings and in the accessibility of important parts are rather to be sought, than the elimination of drag-producing bodies.

The case is similar as regards weight reduction. Still there are possibilities here for improvements in the further development of girder construction, the employment of more suitable materials, etc.

The connection between weight and drag, if aircraft of like speeds are compared, is determined by the saving in power for a lessening in drag. In general it is

$$W = \frac{75 \cdot N \cdot \eta}{v}$$

in which W = drag of aircraft,

v = speed of aircraft,

N = total engine power,

η = efficiency of aircraft.

With constant aircraft speeds, the horsepowers of two aircraft may be compared by the formula

$$N_2 = \frac{W_2}{W_1} N_1$$

in which

$$W_2 < W_1$$

$$v_2 = v_1$$

If G_{bo} is the fuel and oil consumption per HP and per hour, and t is the flight time in hours, then the fuel saving for any drag diminution is given by the formula

$$\Delta G_{bo} = G_{bo} \cdot N_1 \cdot t \left(1 - \frac{W_2}{W_1}\right) \dots \dots \dots (7)$$

It is here assumed to be a question of only small changes in drag and that, in throttling the fuel, only an insignificant loss of efficiency of the engine occurs.

If then $W_2 > W_1$ and $v_2 > v_1$, the increase in fuel consumption with increased aircraft speed is

$$\Delta G_{bo} = G_{bo} \cdot N_1 \cdot t \left\{ \left(\frac{W_2}{W_1}\right)^{3/2} - 1 \right\} \dots \dots \dots (8)$$

If we wish, with traffic aircraft, to adopt an arrangement which, with small space for passengers and freight, will enable the reduction of the total drag, the question arises as to whether, in the particular instance, it is more economical to reduce the flight time or the weight of fuel.

It follows from the above that (for a small reduction in drag, resulting from the saving in fuel due to the engine) it is economical to throttle the engine.

These considerations lead in general to the inquiry, in the case of streamlined bodies, as to what relations there are between content J , surface O , and drag coefficient C_w .

The investigations of Prandtl-Fübrmann, which must be considered fundamental, are based on models having the same cubical contents and the same surface (Hütte I, 1915, p.359).

From a purely theoretical point of view, the best shape would be that offering the least total resistance for a given capacity. Nevertheless the spindle-shaped body with the best drag coefficient is not the most favorable for the construction of an airship. According to whether it is rigid or non-rigid, it must be determined when, with a constant capacity J , the surface O (for non-rigid) and the weight G_g (for rigid airships) is the smallest. Above all else, its controllability and matters pertaining to the hangar play the deciding role.

For ascertaining the most favorable flight speed* it is necessary, for the sake of economical operation, to be able to change the aircraft speed at will, without loss of power. Such speed changes are effected through switching individual engines on or off.

The attempt to calculate the distance flown with different numbers of engines running, on the assumption of unvarying efficiency, offers no prospect of success, since η (as shown by Fig. 4) is greatly affected by changes in the speed of the aircraft.

* P. Renard, Les voyages économiques en aéronef (La technique aéronautique, 1910, Vol. II, p.1) and C. Wieselsberger, Göttinger (Zeitschrift für Flugtechnik und Motorluftschiffahrt, 1913, p. 16) have drawn the power curves in terms of the aircraft speeds and determined graphically the most favorable flight speeds.

3. Distance Flown and Useful Load.

The expression of the useful load with reference to the distance flown is derived from Professor Parseval's formula.

If the drag-weight ratio of the aircraft is K' (ratio of drag W to weight G), then $W = K' G$.

It has been found that $1/8$ may be assumed for a good airplane. With a propeller efficiency of $\eta_p = 0.75$, the work done by the engine during a flight s is:

$$A = s \cdot G \cdot 0.167$$

Now one HP generates $270,000 \text{ kgm/h} = 0.27 \text{ kmt/h}$ and consumes about 0.25 kg/h of fuel and oil. Hence for generating 1 kmt we require $\frac{0.25}{0.27} = 0.93 \text{ kg}$ with a throttle loss of about 1 kg of fuel. The fuel consumption

$$B = s \cdot G \cdot 0.167 \cdot 1 = s \cdot G \cdot 0.167 \text{ kg.}$$

The fuel consumption during flight results in a loss of weight dG :

$$- dG = G \cdot ds \cdot K \quad (K_{\text{airplane}} = 0.000167 \text{ for } G \text{ in tons}).$$

Hence

$$s = \frac{1}{K} \cdot \ln \left(\frac{G_0}{G} \right)$$

in which

G_0 = weight of aircraft at start,

G = weight of aircraft at finish.

If the fuel load is placed at 20% and the useful load is likewise placed at 20% of the total weight, then the distance flown by the airplane in still air is $s_{\text{airplane}} = 1380 \text{ km}$ (which

is a very favorable calculation).

In the case of an airship, W is constant.

With a propeller efficiency of $\eta_p = 0.75$, the work done by the engine for the flight distance s is

$$A = \frac{s \cdot W}{\eta_p}$$

and the fuel consumption

$$B = A \cdot l = 1.33 \cdot s \cdot W \text{ kg.}$$

If we take $\frac{1}{32.5}$ as the ratio of drag to total lift, then with a fuel load equal to 20% of the total load, the distance flown by the airship will be $s = 4880 \text{ km.}$

Since, however, we have the ratio

$$\frac{\text{total lift}}{\text{own weight}} = \frac{100}{40}$$

with the unfavorable system of the rigid airship for useful load, 30% and more can be reserved for fuel. (For 30% fuel load, $s_L = 7330 \text{ kg.}$)

The drag of an airplane is generated chiefly by the supporting surfaces. Any considerable improvement in the ratio of the drag to the weight is therefore not to be expected through enlargement of the dimensions of an airplane and any increase in its economical radius of action in this manner does not appear possible.

If we now consider the radius of action of airships, the comparison of useful load and fuel load for rigid airships in Fig. 5 shows immediately that on long voyages an extraordinary decrease

in weight results from the consumption of fuel.

For example, it amounts to 15,000 kg. for a 55,000 cu.m. airship in 50 hours of flight. As a result of this lightening, the airship climbs

$$\Delta H = 18,400 \log \left(1 - \frac{g}{G}\right) \text{ meters}$$

in which g = loss in kg.

G = total weight of airship in kg.

$$\Delta H = 18,400 \log \left(1 - \frac{15,000}{64,000}\right) = 1620 \text{ meters.}$$

If the equilibrium altitude were 2500 m. on starting, the loss of gas in climbing 1620 meters higher would amount to

$$0.145 \cdot 55,000 = 8000 \text{ cu.m.}$$

The avoidance or diminution of this loss of gas resulting from the fuel consumption constitutes an important problem in solving the question of airship transportation in the economical sense.

As a means of obtaining ballast, we have the air, the exhaust gases, and the fuel itself at our disposal. The utilization of the air and the moisture it contains for obtaining ballast is impracticable, on account of the apparatus required and the often small proportion of moisture present.

From the combustion of gasoline and benzol, water and carbon dioxide are obtained. These combustion products must be reduced to a minimum volume and normal temperature before they can be utilized as ballast.

Without going into the details of the known chemical and thermodynamic processes within the engine, we can call attention to the normal heat balance of an airship engine:

25.73% useful energy,
34.50% radiator water loss,
39.80% exhaust gases,
3.50% radiation,
6.45% friction and change of form.

From one kilogram of fuel 0.69 to 1.8 kg. of combustion water can be theoretically obtained (1 kg. C H yields theoretically 1.46 kg. water at 15°C and 760 mm. Hg.). Practically, with a variation of the air excess between 10% and 20%, we can expect to obtain about 90% of the theoretical combustion water.

The calculation of a plant for recovering the water contained in the exhaust gases is based on the normal radiator dimensions. The relative radiator efficiency decreases with increasing flight speed.* The drag of the radiator and the velocity of the air through the radiator are diminished by an air scoop placed in front of the radiator.

* In Automotive Industries, Vol. 15, p. 479, airplane radiator experiments are described, inaugurated at the Bureau of Standards in Washington, D. C., by the National Advisory Committee for Aeronautics, in which their head resistance or drag, their resistance to the passage of the air current and their weight with relation to the cooling effect was determined. The ratio of heat energy lost to horsepower expended varied for flight speeds of

29.6 m/s	from 17	to 27.5,
34.0 "	" "	13 " 23.5

according to the kind of radiator.

The airship drag W (equation 3) is:

$$W = \frac{75 \cdot \eta \cdot K \cdot N}{v} = (\sum \zeta_w \cdot F + \sum \zeta_w \cdot j^{2/3}) \cdot \frac{\gamma}{g} \cdot v^2$$

in which η = efficiency of airship,

K = r.p.m. of engine,

N = HP of engine.

The front surface F of ordinary radiators on different aircraft, provided with like engines of 245 HP, was

For airplane with $v = 50.0$ m/s; $F = 0.203$ m².

" airship " $v = 29.3$ " $F = 0.600$ m² without air scoop.

" " " $v = 34.6$ " $F = 0.600$ m² with air scoop.

For the front surface of radiators.

$\zeta_w = 0.53$ for 50 m/s.

$\zeta_w = 0.50$ for 35 "

$\zeta_w = 0.495$ for 30 "

A favorable speed for the radiator efficiency is generated in the radiator by the air scoop. Experiments with radiator air scoops in the bow of the engine nacelle demonstrated that the radiator drag was diminished 57%.

In order, with an airship engine, to remove 24.5% of the total amount of heat by means of the radiator, the latter's share of the total drag area at 34.6 m/s flight speed with radiator air scoops was

$$\sum \zeta_{wK} \cdot F_K = 0.43 \cdot 0.50 \cdot 5 \cdot 0.60 = 0.646 \text{ m}^2.$$

For cooling the exhaust gases, a further 36.5% of the heat had to be removed by the radiator.

We have no experimental values for gas coolers with air scoops.

We assumed in advance (in order not to make too favorable calculations) that the front surface of the radiator had to be exposed to the full flight speed and we obtained for the radiator, as its part of the drag area

$$\Sigma \xi_{wK} \cdot F_K = 0.50 \cdot 5 \cdot 0.60 \cdot \frac{0.365}{0.245} = 2.235 \text{ m}^2.$$

The flight speed v with ordinary coolers or radiators is

$$(\Sigma \xi_w \cdot F + \Sigma \xi_{wK} \cdot J^{2/3}) = 12.75 \text{ m}^2.$$

$$v^3 = \frac{75 \cdot 0.72 \cdot 5 \cdot 245}{12.75 \cdot 0.125} = 4140$$

$$v = 34.6 \text{ m/s.}$$

For airships with gas coolers the speed v_g was:

$$v_g^3 = \frac{75 \cdot 0.71 \cdot 5 \cdot 245}{(12.75 + 2.235) \cdot 0.125} = 3480$$

$$v_g = 32.65 \text{ m/s instead of}$$

$$v = 34.6 \text{ m/s without exhaust gas cooler.}$$

By installing a gas cooler, the ship's speed was accordingly reduced 2 m/s, an amount which could probably be reduced to 1.4 m/s by using air scoops. Air scoops naturally add weight, but have the great advantage, in temperature and speed variations, of keeping the drag at a minimum on account of their streamlined shape.

4. Practical Experiments have Thus Far
Given the Following Results.

(a) A gas cooler without air scoop, with about 3 sq.m. front surface, was installed on an airship with a speed of 30 m/s, and delivered about 100% of the weight of the gasoline consumed.

The efficiency was very good, but the thin channels soon rusted and could not be cleaned during the trip.

(b) In order to lessen the air resistance, the cooler (or radiator) was installed in the nacelle as a "rotor" and was expected to draw its own cooling air. It was thought to save energy by driving the rotor direct from the engine.

After several unsuccessful attempts, one experiment produced about 6% of the weight of gasoline consumed, in the form of water. This rotary exhaust cooler with 20 HP drive was too small. The channels, which were considerably larger than the ones in the stationary gas cooler, became clogged with rust after a few hours' use. It was difficult to collect the emerging water as it was immediately evaporated by the draft from the rotor. A larger plant would occupy too much room in the nacelle.

(c) Experiments in condensing the water vapor in the exhaust gases by means of a spray of water are being tried and have given 60% of the fuel weight, as the gain in water.

Methods a and c are the most promising. With a maximum energy outlay of 30% of the total engine power, an efficient water ballast winner can be operated.

The attempts to obtain the CO_2 in the form of ballast, by spraying milk of lime into the exhaust pipes, or absorbing the CO_2 with charcoal or coke, failed on account of the impossibility of chemical regenerations during the voyage.

PART II.

Introduction.

Peace-time aviation can only be developed from economical view points. The general technical hypotheses were set forth in Part I.

We shall now discuss the matter of cost for its limited field of application and for its characteristic technical conditions, and endeavor to determine how an airship should be constructed, in order to fulfill the economical conditions of the purpose for which it is designed.

During the War, the constructors bent all their energies to increasing the total carrying capacity and total efficiency of aircraft, and if we should represent the progress made* by a curve as a function of the time, we could surely expect a smaller tangent for the curve during the next five years. Great improvements can not be expected in the immediate future.

The carrying capacity determines the useful load and the ef-

* In "Flight" of January 30, 1919, the English Air Ministry reports for the period from August, 1914, to August, 1918, an increase of 450% in the carrying capacity of airplanes and of 55 and 790% respectively in the speed and endurance of airships.

iciency determines the cost of fuel. Consequently, we can not expect any considerable increase in the relative weight of passengers and freight, nor any considerable decrease in the fuel cost.

We must therefore devote our attention to the aircraft itself and its construction, while taking its short term of life into consideration. Statistics concerning the life of airplanes and airships have thus far been impossible.

The relatively high stresses on the essential structural parts of aircraft in comparison, for example, with locomotives and steamboats, constitute the chief reason for their short life. The strengthening of these parts at the cost of the useful load is largely impracticable and there accordingly remains, as the ultimate solution, only the lessening of the cost of construction by quantity production of exchangeable parts.

Experience has shown that the various parts of aircraft differ greatly in durability. While, for example, one part is only good for 100 hours of flight, another part may stand 6000 hours.

Conditions demand the greatest possible standardization and, above all else, the manufacture of exchangeable parts. Economical quantity production in detail, however, is not at first strictly applicable to aircraft, since the machinery equipment of a factory would need to be adapted to each smallest part and process.

The application of this principle would enable the production of say, 300 aircraft of the same type in a working day, a number for which there is yet no need but which may soon come within the realm of possibility.

We must therefore be satisfied with a compromise and endeavor to bring the fundamental requirement, the continuity of the supply of materials for making the larger parts of the aircraft into harmony with a definite yearly production of aircraft, for which there will always be a demand.

I. CONSTRUCTION.

The necessity of keeping the production cost of the airships low in comparison with the running expenses of the airship lines, leads to a deeper investigation into the methods of making the main part of a rigid airship.

In order to determine the cost of the three factors:

1. Materials,
2. Wages,
3. Overhead expenses,

in building an airship, the following exhibit of the bracing strips employed in the framework of a 55,000 cu.m. airship serves first.

Bracing strips on frame.

Bracing: Thickness: Number per: Strips of like: Number : % of total
strips: in mm. : ship. : cross-section : per ship: number

a/b	: 0.4	: 3,300	:		:		:		:
a/b	: 0.5	: 15,000	:	a	:	24,800	:	9.7	:
a/b	: 0.6	: 6,000	:		:		:		:
b/b	: 0.4	: 11,000	:		:		:		:
b/b	: 0.5	: 13,000	:	b	:	72,900	:	29.0	:
b/b	: 0.6	: 300	:		:		:		:
c/d	: 0.4	: 150	:	c	:	150	:	0.1	:
d/d	: 0.4	: 150	:	d	:	450	:	0.2	:
e/e	: 0.4	: 8,600	:		:		:		:
e/e	: 0.5	: 7,000	:	e	:	36,200	:	14.4	:
e/e	: 0.6	: 2,500	:		:		:		:
f/f	: 0.5	: 1,100	:		:		:		:
f/g	: 0.4	: 7,500	:	f	:	10,300	:	4.1	:
f/g	: 0.5	: 600	:	g	:	8,100	:	3.2	:
h/h	: 0.4	: 3,200	:		:		:		:
h/h	: 0.5	: 1,100	:	h	:	23,850	:	9.5	:
h/i	: 0.4	: 15,000	:		:		:		:
h/i	: 0.5	: 250	:	i	:	15,250	:	6.1	:
k/k	: 0.4	: 15,000	:		:		:		:
k/k	: 0.5	: 5,200	:		:		:		:
k/k	: 0.6	: 3,000	:		:		:		:
k/l	: 0.4	: 4,000	:	k	:	52,900	:	21.0	:
k/l	: 0.5	: 2,500	:	l	:	6,500	:	2.6	:
m/m	: 0.4	: 150	:	m	:	300	:	0.1	:
125,600						251,200		100.0	

The variation of 0.2 mm. in the thickness of the sheet metal makes no difference in the manufacture of the strips, so that it is seen from the last column, that one kind of strip constitutes 30%, in a round number, of the total number of strips used on the airship.

A day's output of a stamping machine consists, for both processes of cutting and stamping, of 6000 to 9000 pieces, according to the size of the strips.

If, now, the manufacture were conducted on the principle

that the simplest part with its process determines the machine number for all the other parts, then for the strip 1, with a requirement of 6500 strips per airship, a day's work would be reached and one airship would be completed every day.

A monthly output of 25 airships does not come at once into the realm of possibility. We must consider the relation between the total time required and the uninterrupted operation of an airship on the same part.

If, for instance, an airship is to be completed every month, then, as soon as one is removed from the assembling hall, all the materials must lie ready for the next, that is, the individual processes must follow one another in such manner as not to interrupt the movement of the materials, if another airship is to be completed on time.

If the processes involved in the construction of the frame* are divided into:

* The "Aeroplane" of August 20, 1919, describes the construction of the English rigid airship made of duralumin by the firms of Vickers Ltd., Armstrong, Whitworth & Co., Ltd., and Wm. Beardmore & Co., Ltd., as likewise of the wooden frame airships made by the Short Brothers, in Bedford.

The numerous illustrations show the individual processes in the construction of the airships and detailed descriptions picture the characteristic structural peculiarities.

The three operations:

Riveting the girders,
Assembling the transverse frames and
Assembling the whole framework,

are illustrated by pictures of the workshop with female workers, of the transverse frame shop with suspension devices and by many views of the assembling hall. An account is also given of the many subsidiary industries connected with airship building.

1. Machine work with unskilled operatives,
2. Riveting the girders,
3. Assembling the transverse frames,
4. Final assembling of airship,

it may be noted that the cutting and stamping of the strips and plates, as well as riveting the girders, constitute pure quantity production, since these operations are performed by unskilled female operatives. (It has been found that women are better adapted than men for such uniform mechanical processes which require no great physical exertion.)

In assembling the transverse frames, one-third of the work is done by mechanics and two-thirds by unskilled assistants; the final assembling of the whole framework, by one-fourth mechanics and three-fourths unskilled assistants.

Since, as already mentioned, it is impossible to perform all the work by quantity production, it remains to be decided where to draw the line between it and unit production.

If we hold to our program of completing one airship per month, then complete individual production with the four processes would require a period of four months, one month for each workshop to construct or assemble the parts for one airship. Any shifting in the order of finishing the individual parts would be entirely allowable and the strips stamped in the first workshop, on the last day of the stipulated delivery month, could be riveted to the girders in the next workshop any time during the next delivery month.

As soon as a change is made to the plan of adjusting one machine to the number of like strips required for several airships, then the work in all the shops must be done in accordance with a definite plan, determined in the supervising office, and no shifting is possible.

Since girders and transverse frames are bulky parts, it is advisable, for the sake of saving space, to construct them only for one airship, instead of for several at a time.

The time consumed affects the operating capital, since the longer the flow of materials continues, the more money is tied up. The uninterrupted operation of a machine is a source of economy.

The arbitrary production of an excessive number of parts incurs the risk of having a large number left over in case the particular type should be abandoned, while lacking parts must be made by expensive overtime work, both of which are highly uneconomical.

The same as for the framework, the work on the engines, nacelles, etc., may be systematically planned. Conditions here are more favorable, since more units of the same design are required per ship.

Many firms have introduced cost of production cards, on which every piece, together with cost of labor and material, as well as overhead costs and deterioration are entered.

Since the writer has no such system at his disposal, he found himself compelled to get at the cost of production in an-

other way.

The weight of every individual was determined part for a series of airships. For every class of structural parts, a definite factor was obtained, as for example, 50% for lattice strips.

With the aid of carefully prepared weight lists the material actually consumed was determined. Multiplying this by the current prices gave the cost of materials.

In a similar way, the time required to make each part was found. Multiplying by the customary wages, and adding, gave the total cost of labor.

2. ESTABLISHMENT OF AN AIRSHIP LINE.

The economical adaptation of an airship to traffic purposes is demonstrated, when it shows sufficient advantages in comparison with competing means of traffic, due to its utilization of the air as a means of conveyance over both land and sea. The conditions are most favorable for airships in crossing a region of alternating land and water, thus avoiding the necessity of transfers.

In competition with existing land or water conveyances, airships have the advantage of speed and the saving in time in going from one place to another determines the allowable increase in fare.

Assuming that airplanes in their present form have a maximum economical flight distance of 5100 km., they will be adapted to

establishing communications between places where the railroads make long detours and will supplement the latter, in a general way, like automobiles, but over longer stretches. They will also be employed where the deciding factor is the saving of time in comparison with the railroad or ship, especially where there is provision for emergency landings.

It would, however, be practically impossible for them to cross the Pacific Ocean without replenishing their fuel supply from mother ships which could be stationed at intervals of about 1500 km. This accordingly constitutes the principal field of operation for airships.

Trans-Atlantic Traffic.-- Even in flying over land, the airship has the advantage in its ability to carry larger and indivisible objects.

The distance an aircraft can fly depends on the four quantities:

1. Lift-drag ratio,
2. Rate of fuel consumption,
3. Efficiency of propeller,
4. Ratio of fuel weight to total weight.

It has already been mentioned that any considerable improvement in the first three is not immediately probable. It is furthermore evident that the ratio of the fuel weight to the total weight may be varied at will by changing the useful load. In this connection, the question of flight distance for economical purposes could be based on the ratio of fuel weight to useful

load.

Instances may occur when it is a question of reaching a given point, at any cost, in the shortest possible time. A relatively small aircraft is better for this purpose when it is possible to make intermediate landings.

If a non-stop flight must be made, the flight distance for a giant airplane with two passengers may be

$$S = \frac{1}{k} \cdot \ln \left(\frac{G_0}{G} \right) = \frac{1}{0.000158} \cdot \ln \left(\frac{100}{62} \right) = 3130 \text{ km.}$$

Such exceptional cases can not however be taken as the basis for an economical calculation.

The preliminary conditions for the economical operation of an air traffic line must accordingly be:

1. Regularity of trips,
2. Nearly constant weight of passengers and freight,
3. Maximum transformation of engine power of fuel consumption into flight performance.

Conditions 1 and 2 depend on meteorological considerations and the necessary remunerative load, while condition 3 is dependent on the construction of the aircraft and stationary adjuncts and the economical production of both.

In discussing conditions 1 and 2, it is quite common to say that those portions of the earth which are inhabited by rich and enterprising men, do not have favorable meteorological conditions.

The union of Europe with North American by an airship line is most enticing to business men on account of the large commerce

and passenger traffic between the two countries.

An inspection of the weather charts shows, however, that the regular operation of such a line the year round is not possible. Throughout the whole distance strong west winds prevail with great danger from storms during the months of September to April and much cloudy weather during the balance of the year. The most favorable months for the direct route between Lisbon and New York are June, July and August, since during this period there are spells of east wind and few clouds and storms south of the fortieth parallel of latitude.

Crossing the Atlantic with airships requires complete weather reports and the best weather predictions and radio-telegraphy. Generally the direct route will not be chosen but detours will be made according to weather conditions. In August, for example, the Northeast trade-wind can be utilized by making a detour to the south.

Since there is room in this article to state only the most general preliminary conditions for the establishment of airship lines, I shall simply call attention to the fact that the Mediterranean Sea and the Pacific Ocean are more suited to airship traffic than the Atlantic Ocean and that consequently the lines London-Cairo-Australia, Cairo-Cape Town, and Francisco-Manila are very promising.*

* See "Segelhandbuch des Atlantischen Ozeans;" Schnell, "Der Flug über den Ozean," Motor, 1919, p.105; "The Aeroplane," August, 1919, p.692, "Air Currents Over the Atlantic Ocean."

3. COSTS OF OPERATION AND UPKEEP.

For determining the cost per km (kilometer-ton) the decisive factors are:*

1. Aircraft production and amortization,
2. Fuel,
3. Gas,
4. Accommodations for pilots and passengers,
5. Service, furniture, spare parts, repairs, etc.
6. Airdromes, hangars, mooring towers, and their amortization.**

The consideration of the relative value of each of the above elements would be too lengthy to take up here. With the present constantly changing values, the actual cost is less important than the relative cost for airships of different sizes.

It has been demonstrated that an airship should have a gas capacity of at least 75,000 cu.m. for a flight distance of 9000 km.

* In "Zeitschrift für Flugtechnik und Motorluftschiffahrt," A. Betz gives the running expenses in relation to the flight distance s and the flight speed v and makes the cost of the aircraft proportional to its weight and the price of the engine proportional to its power (HP).

** In "The Aeroplane" for August 20, 1919, the essentials for an airship are given as follows:

- 1.--An airdrome of 1.5 sq.km.; 2.--A hangar capable of holding two airships; 3.--A mooring tower with a windlass; 4.--A motor car on rails for conducting the airship from the tower to the hangar by means of an electric winch; 5.--Hydrogen plant; 6.--Repair shops; 7.--Meteorologic and radio stations; 8.--Electric signalling stations for night service; 9.--Offices, etc.

For a propeller of given diameter, with a certain diminution of efficiency, the torque and r.p.m. vary according to climbing ratio.

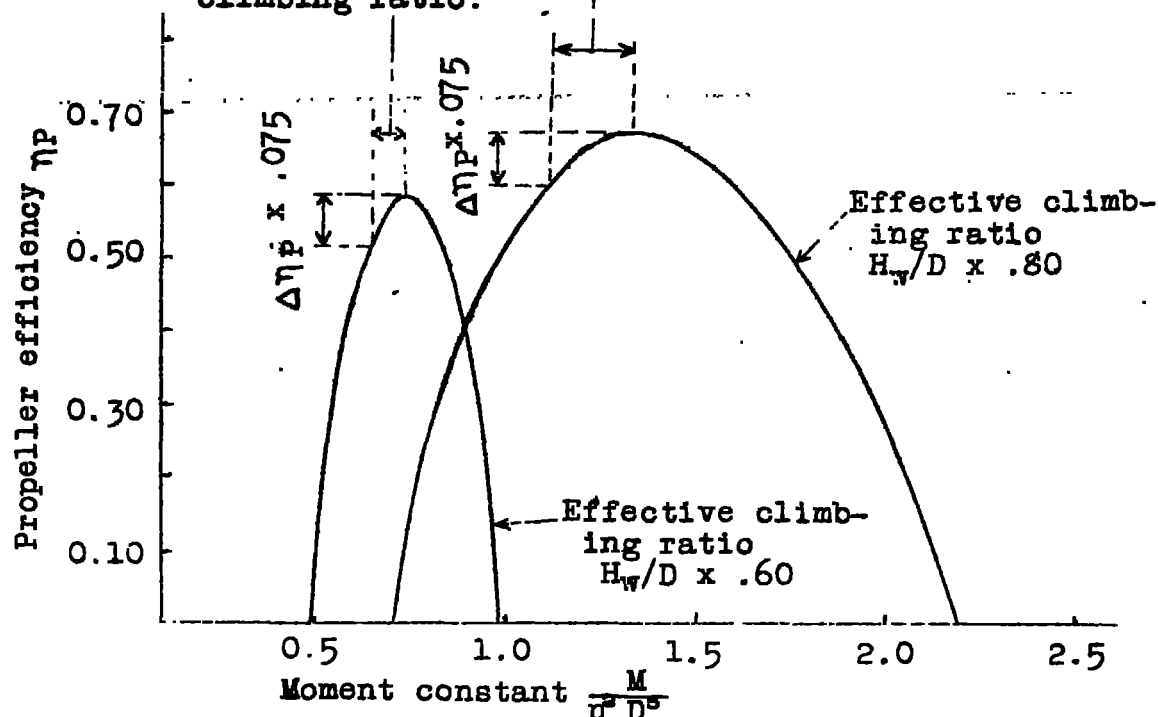


Fig.1. Propeller efficiency in terms of the moment constant

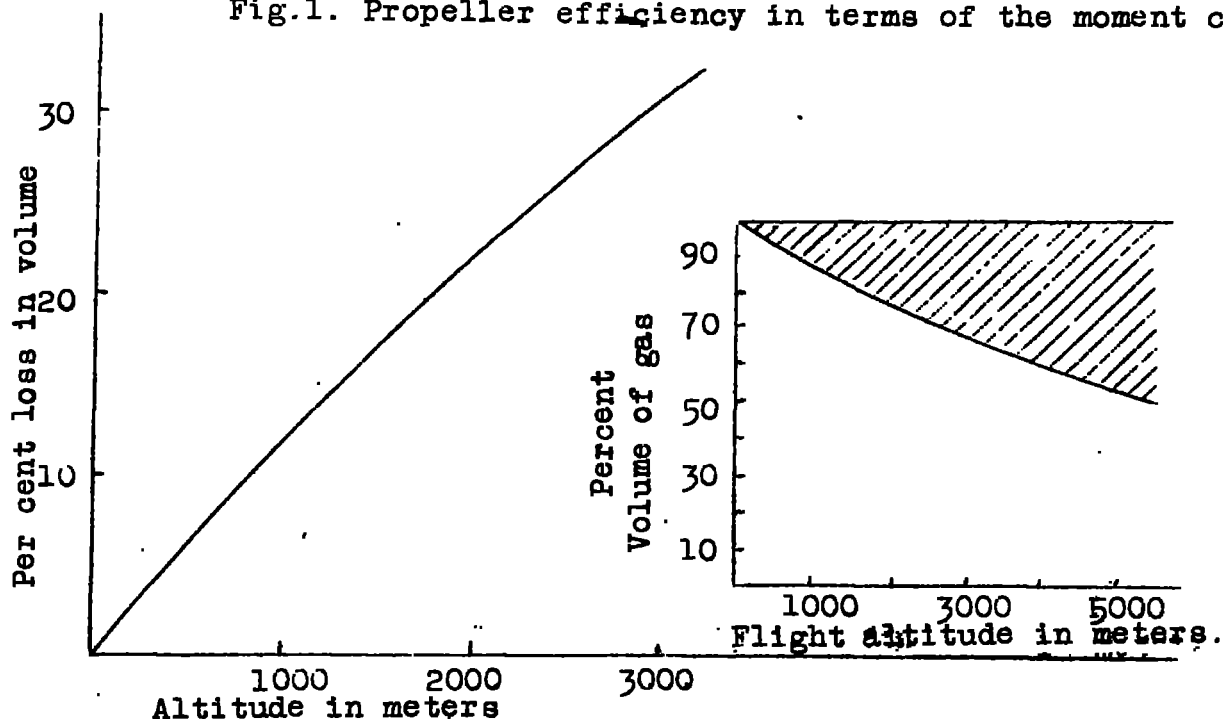


Fig. 2.Utilizable volume of gas dependent on the flight altitude.

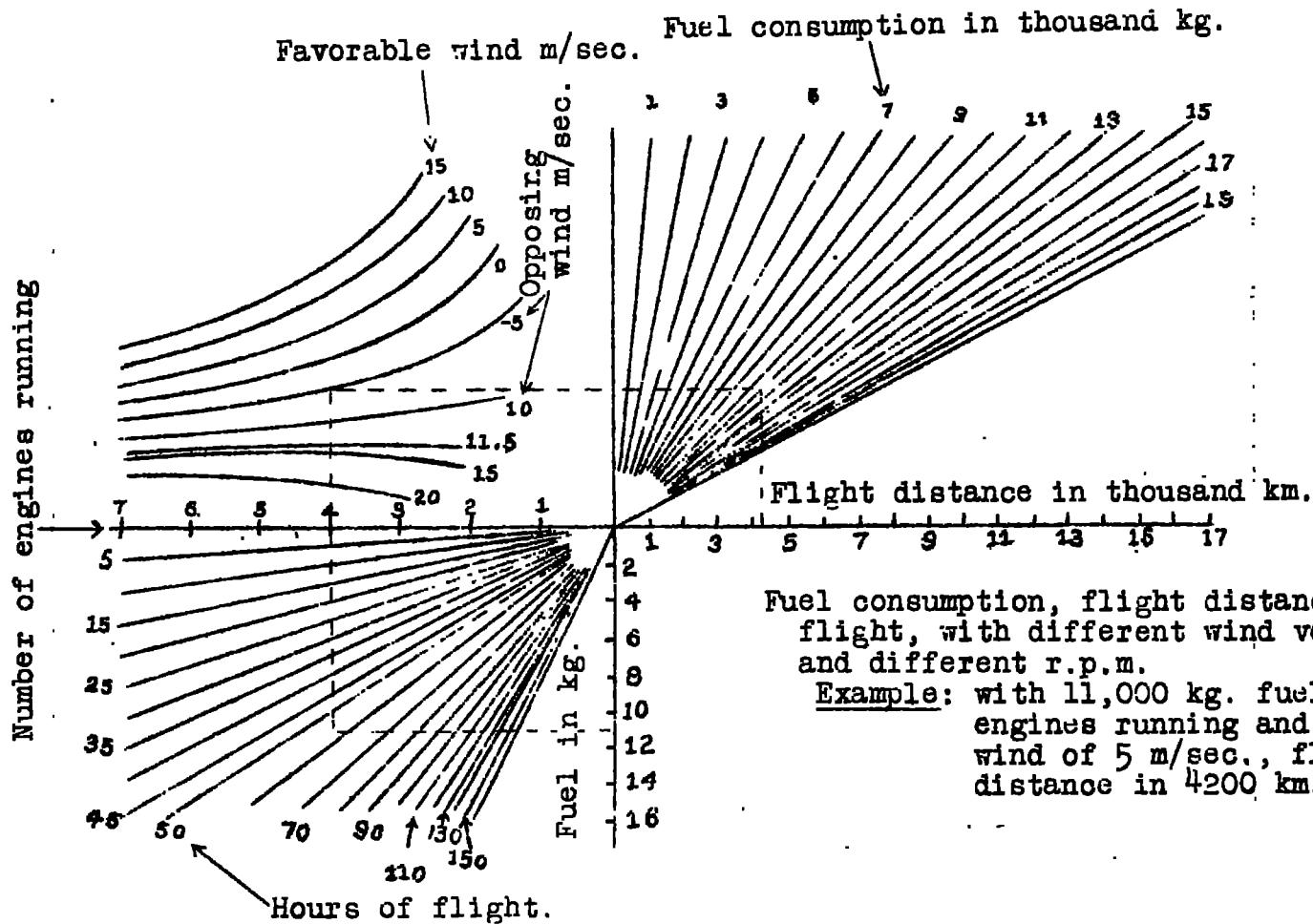


Fig. 3.

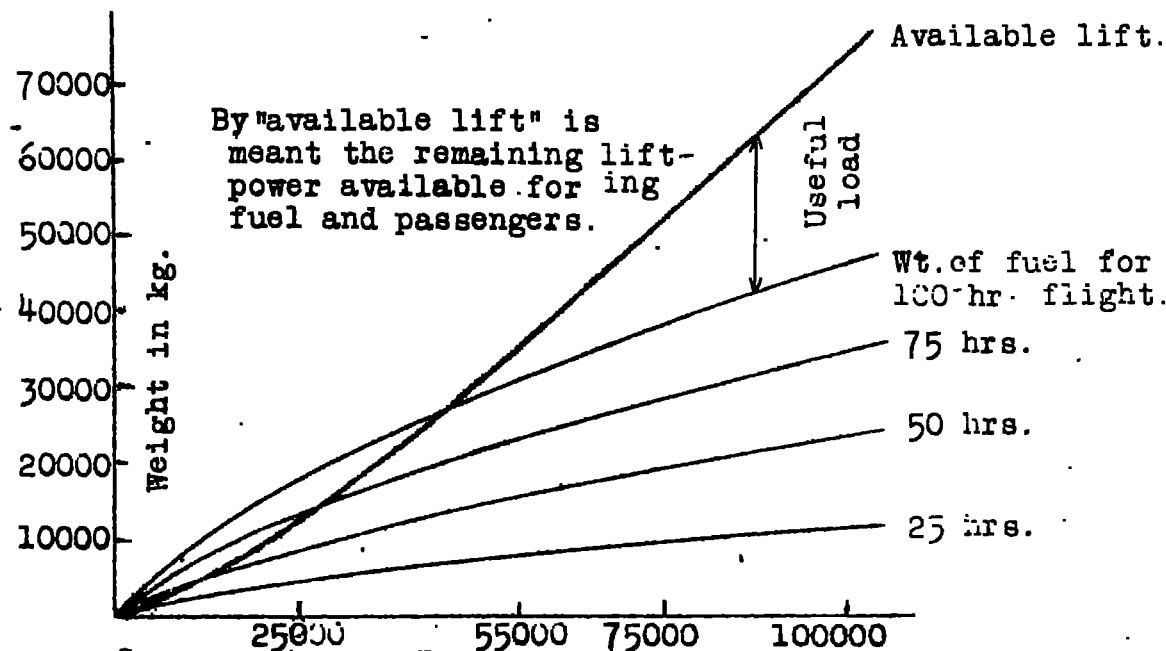


Fig. 5. Available lift, useful load and weight of fuel for rigid airships.

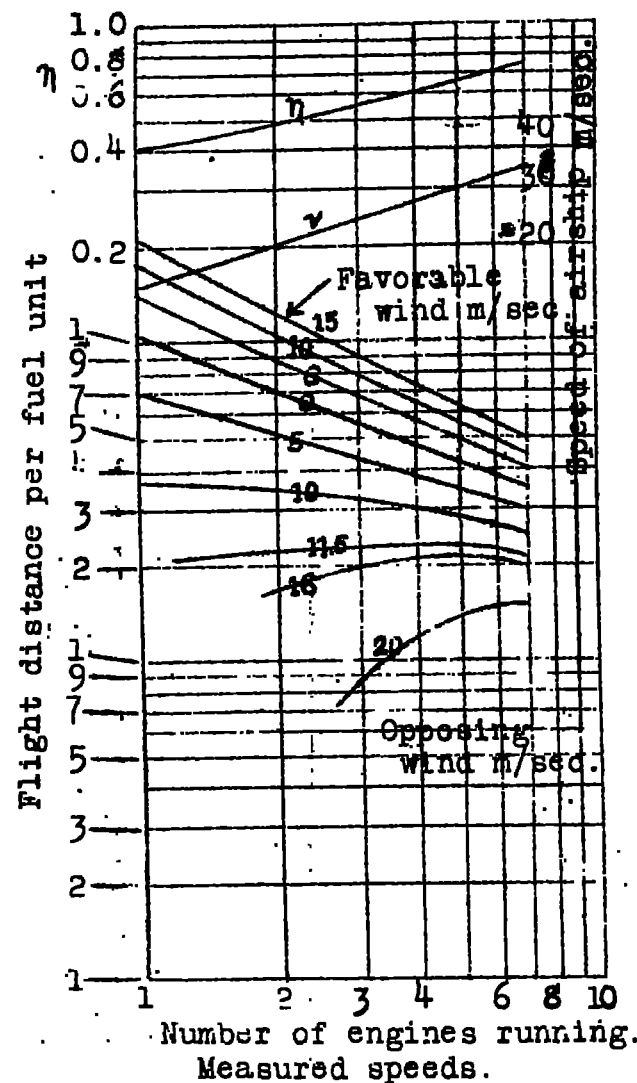


Fig. 4. measured speeds.

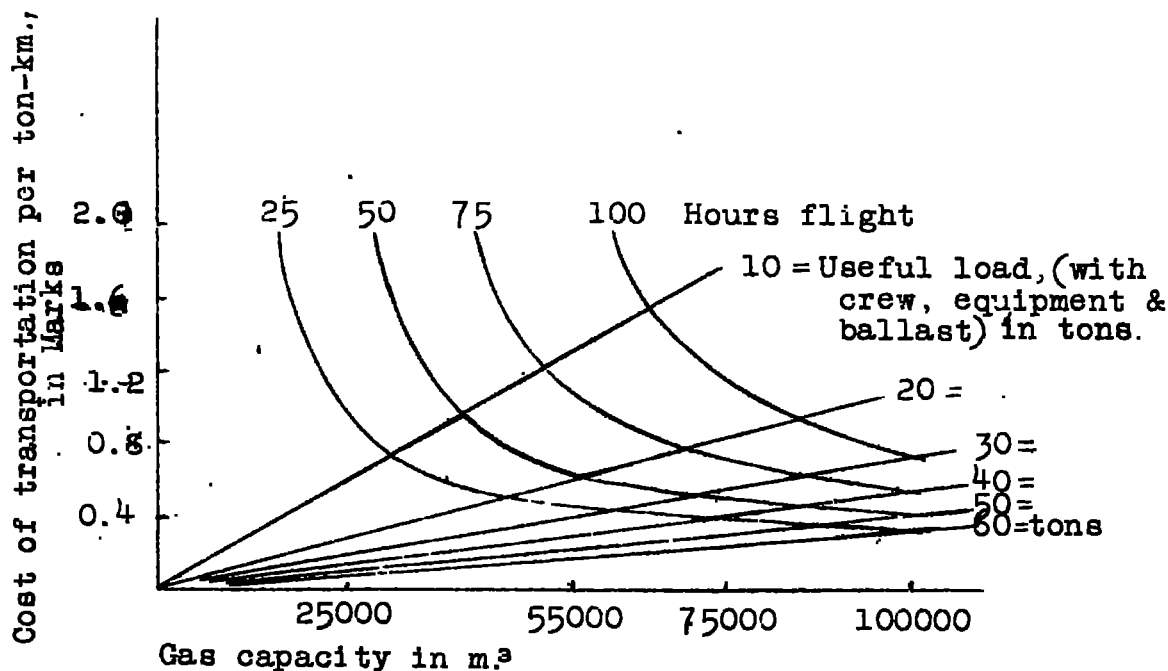
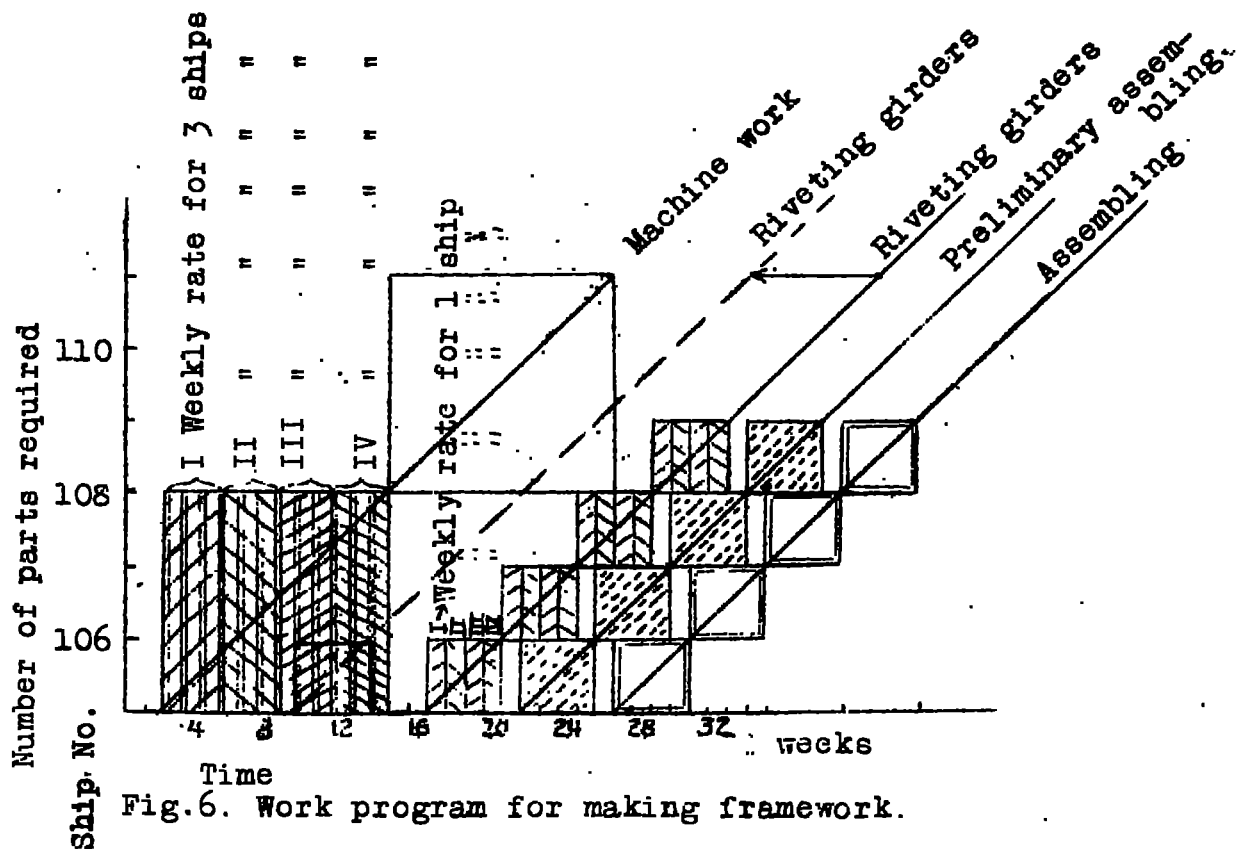


Fig. 8. Cost of transportation per ton-km. on the basis of Jan. 1, 1919.

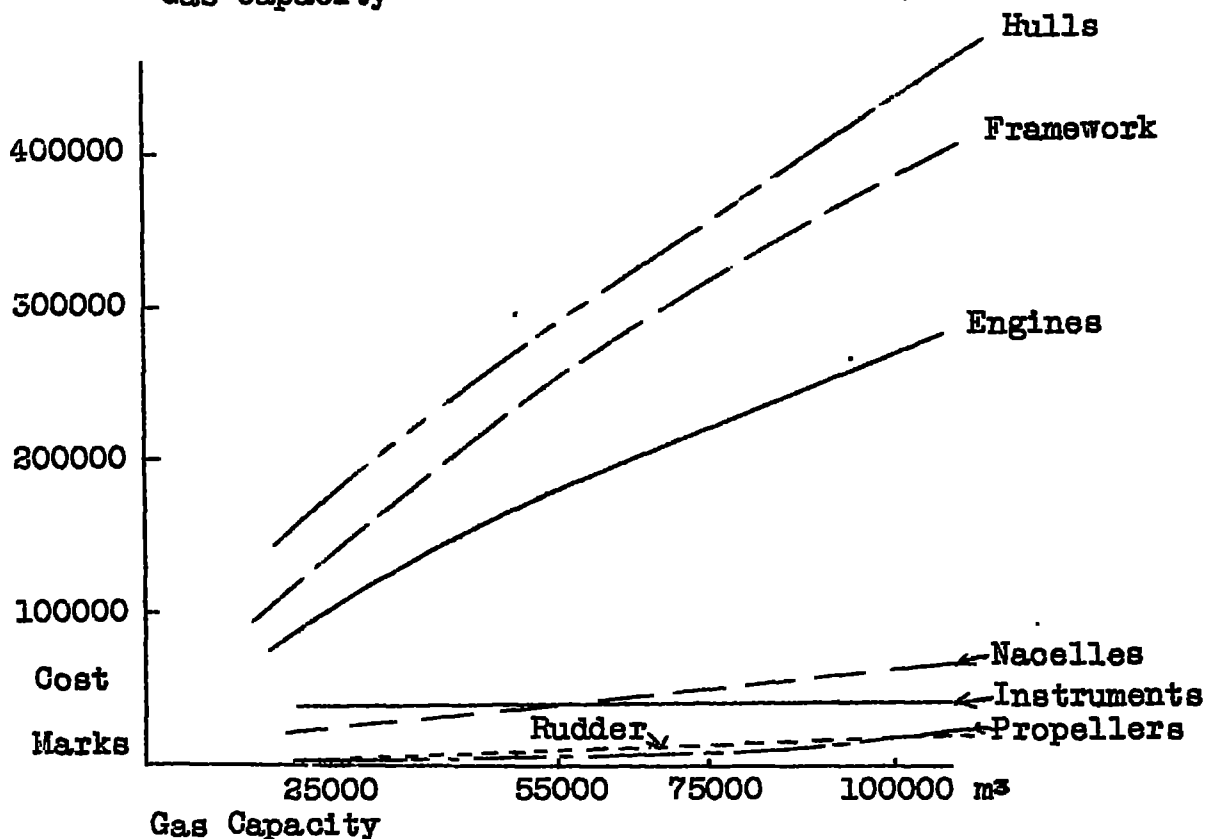
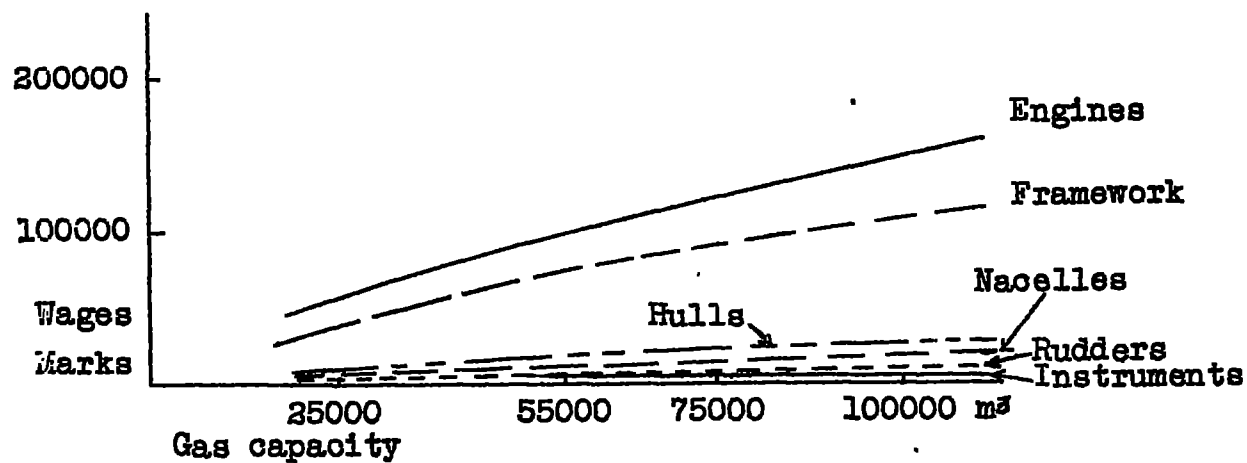


Fig.7. Wages and cost of materials.
(Wages on basis of Aug. 1, 1918.)

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